Instruments for PAMS Upper-Air Meteorological Measurements

Clinton MacDonald, Tim Dye, Charley Knoderer
Sonoma Technology, Inc.
Petaluma, CA

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Sonoma Technology, Inc.

Upper-Air PAMS Background

- Photochemical Assessment Monitoring Stations (PAMS): one upper-air meteorological site per network
  - Four wind and temperature soundings per day*
- Many agencies deployed radar wind profilers (RWPs); several still operate.
- While RWPs provide useful data, aging equipment and related costs are issues.

*http://www.epa.gov/ttnamti1/files/ambient/pams/97workbook11.pdf

Upper-Air PAMS Background

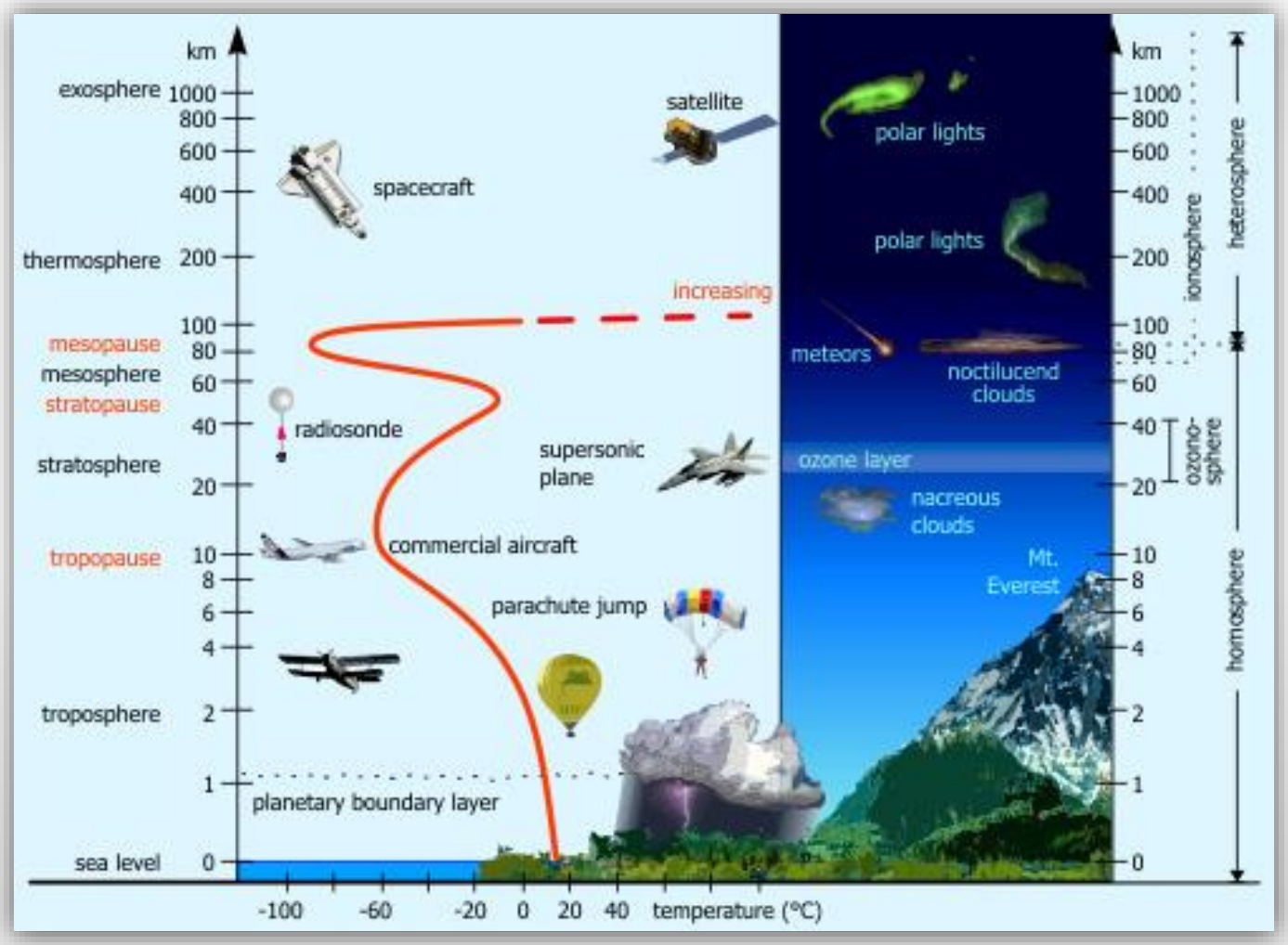
- As part of PAMS re-engineering, EPA proposed a change to allow more flexibility
  - Will only require mixing height measurements
  - Will support measurements of other parameters (winds, temperature, etc.)
- Proposed with the new Ozone NAAQS Rulemaking (June 6, 2013); final rule expected in December 2014

Today's talk

Goal: To provide information on instruments that measure upper-air meteorology to help with future measurement decisions

- Upper-air meteorological basics
- Parameters
- Applications
- Instrument types
- Attributes and costs

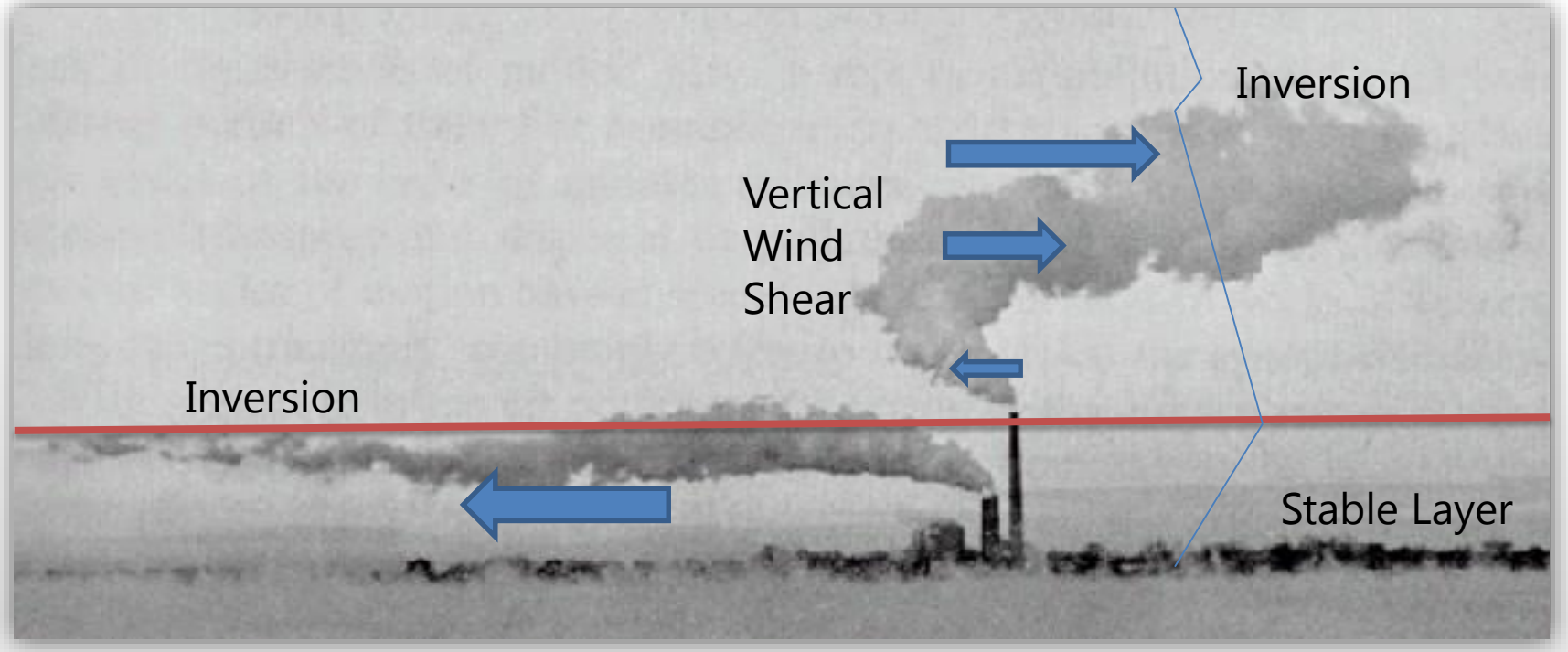
Upper-Air Meteorology



http://www.theozonehole.com/atmosphere.htm

Upper-Air Meteorology

It's a 4-dimensional process



http://www.met.reading.ac.uk/Research/boundary_layer/research/

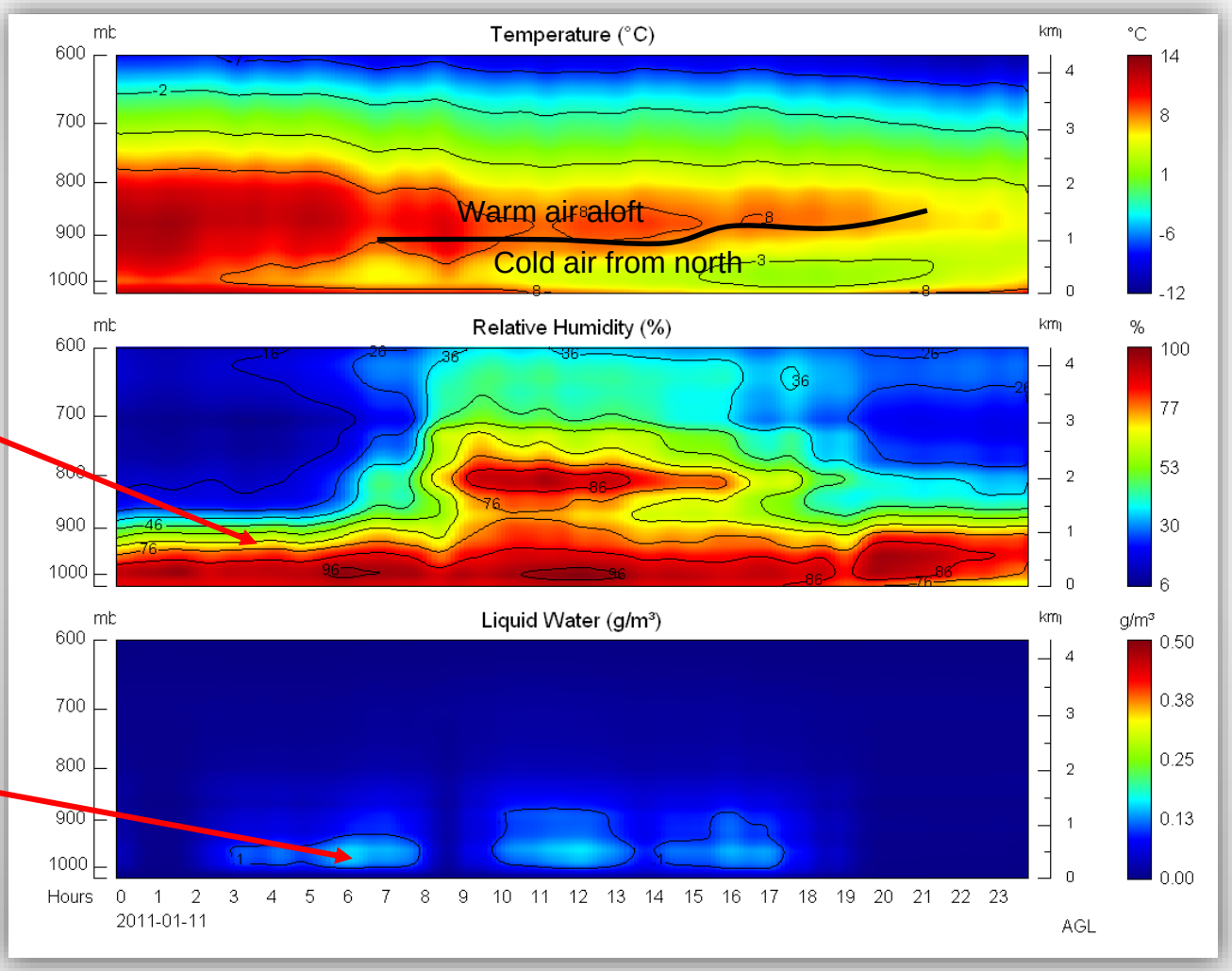
Parameters (and What They Influence)

- Winds
  - Transport, dispersion, windblown dust
- Temperature
  - Stability, inversions
  - Chemistry, dispersion, fumigation
- Mixing height and boundary layers (BL)
- Moisture
  - Clouds, precipitation
  - Chemistry

Temperature

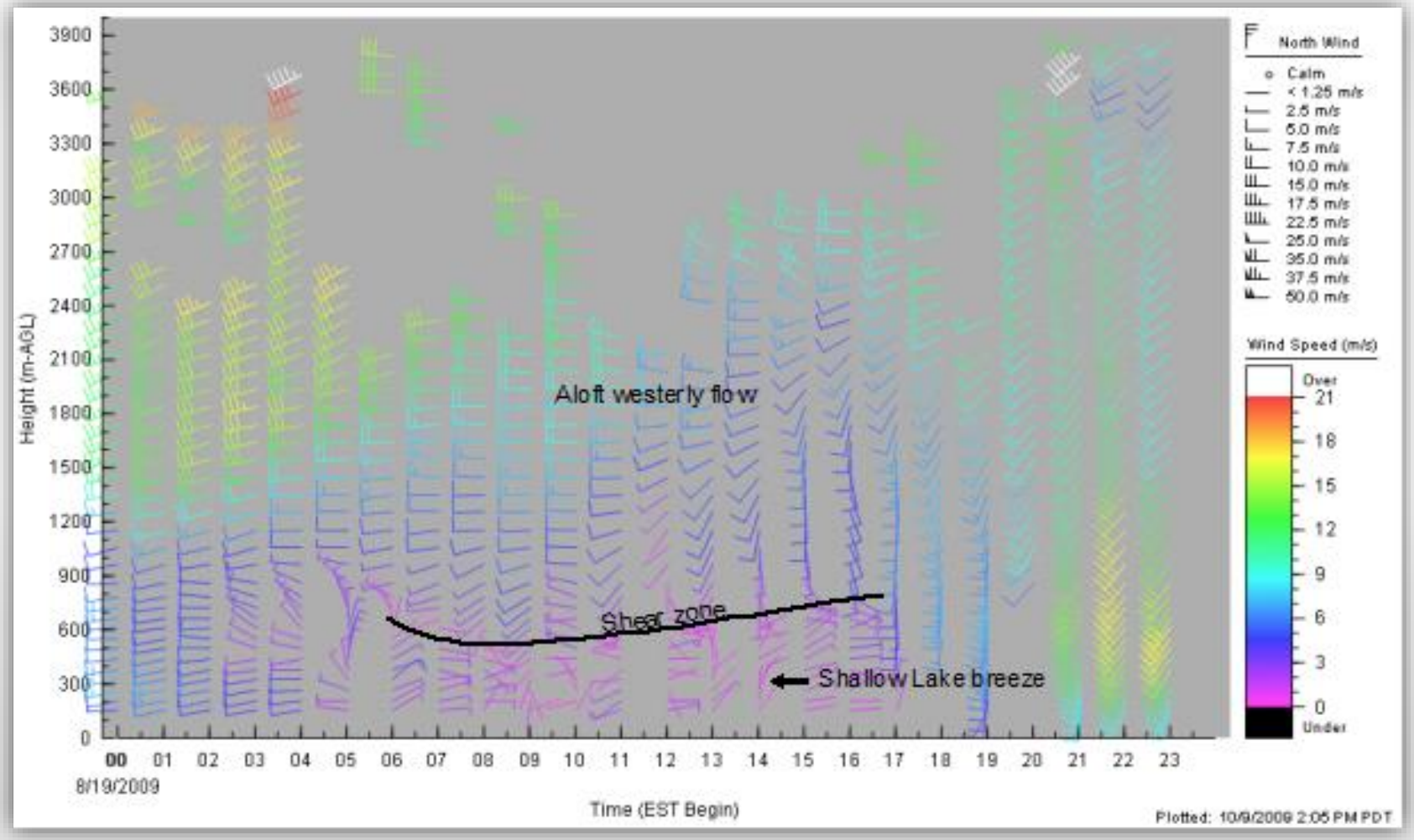
Strong relative humidity (RH) gradient near the top of the cloud layer

Increased levels of liquid water in the cloud layer



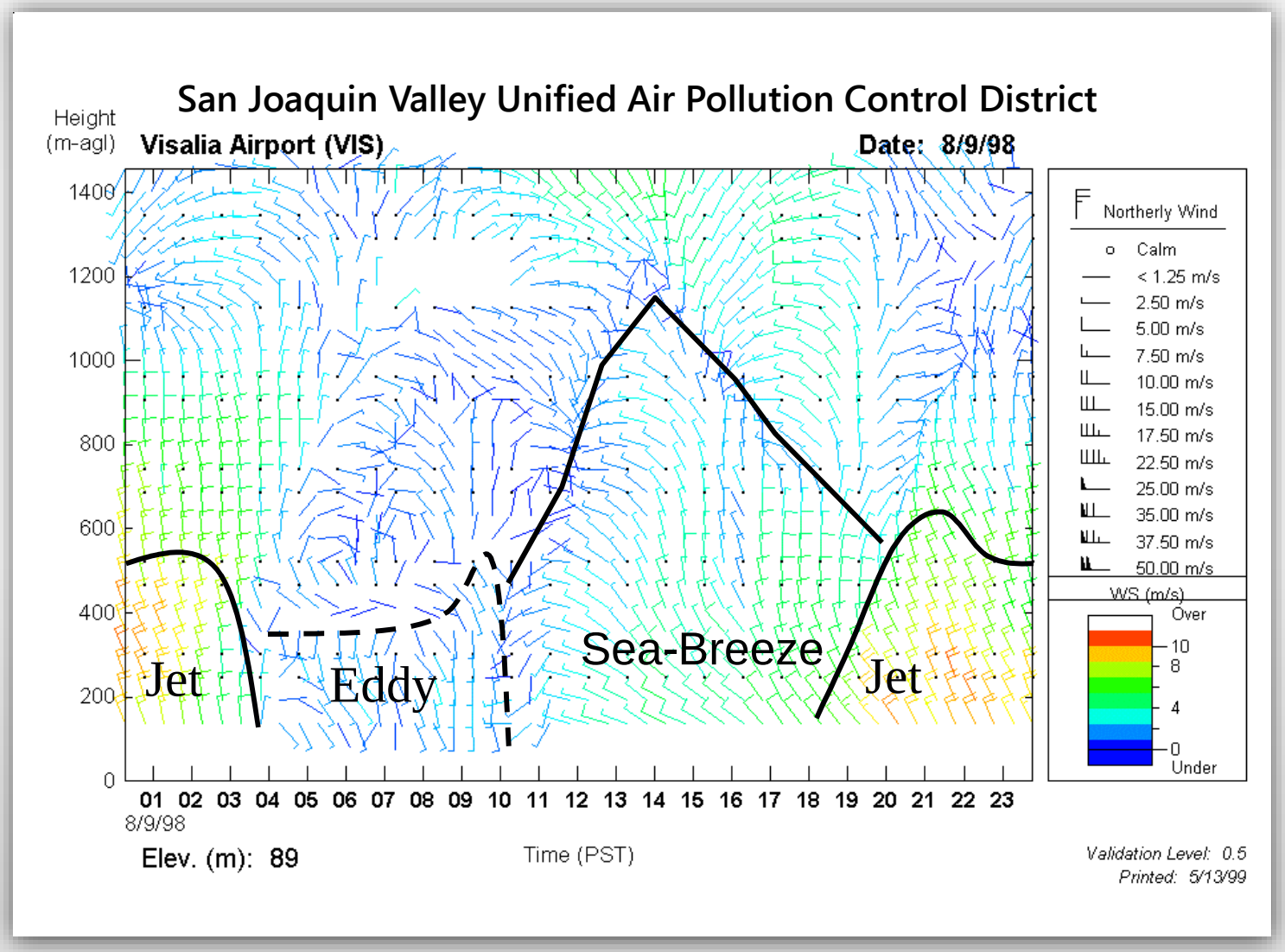
Chevron Oil Platform ST-52B over Gulf of Mexico near Louisiana coast.

Winds

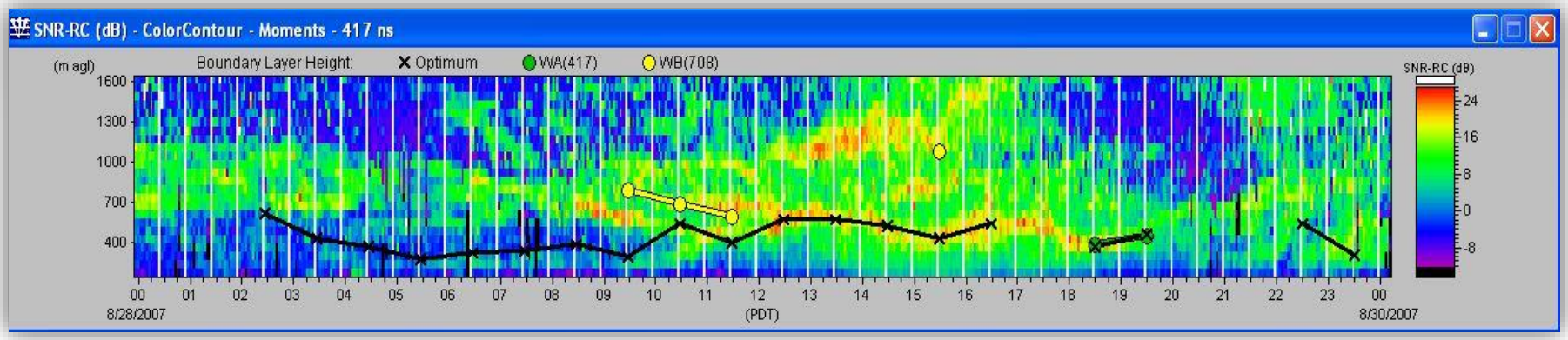


Cleveland, Ohio

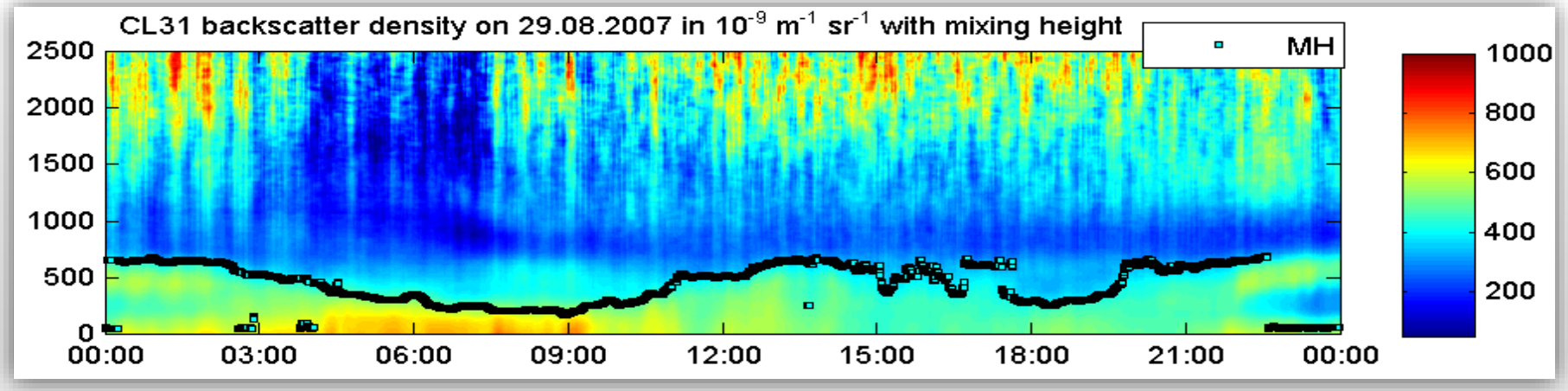
Winds


San Joaquin Valley Unified Air Pollution Control District
Height (m-agl)
Visalia Airport (VIS)
Date: 8/9/98
1400
1200
1000
800
600
400
200
0
Jet
Eddy
Sea-Breeze
Jet
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23
8/9/98
Elev. (m): 89
Time (PST)
Northerly Wind
Calm
< 1.25 m/s
2.50 m/s
5.00 m/s
7.50 m/s
10.00 m/s
15.00 m/s
17.50 m/s
22.50 m/s
25.00 m/s
35.00 m/s
37.50 m/s
50.00 m/s
WS (m/s)
Over
10
8
4
0
Under
Validation Level: 0.5
Printed: 5/13/99

Mixing Heights



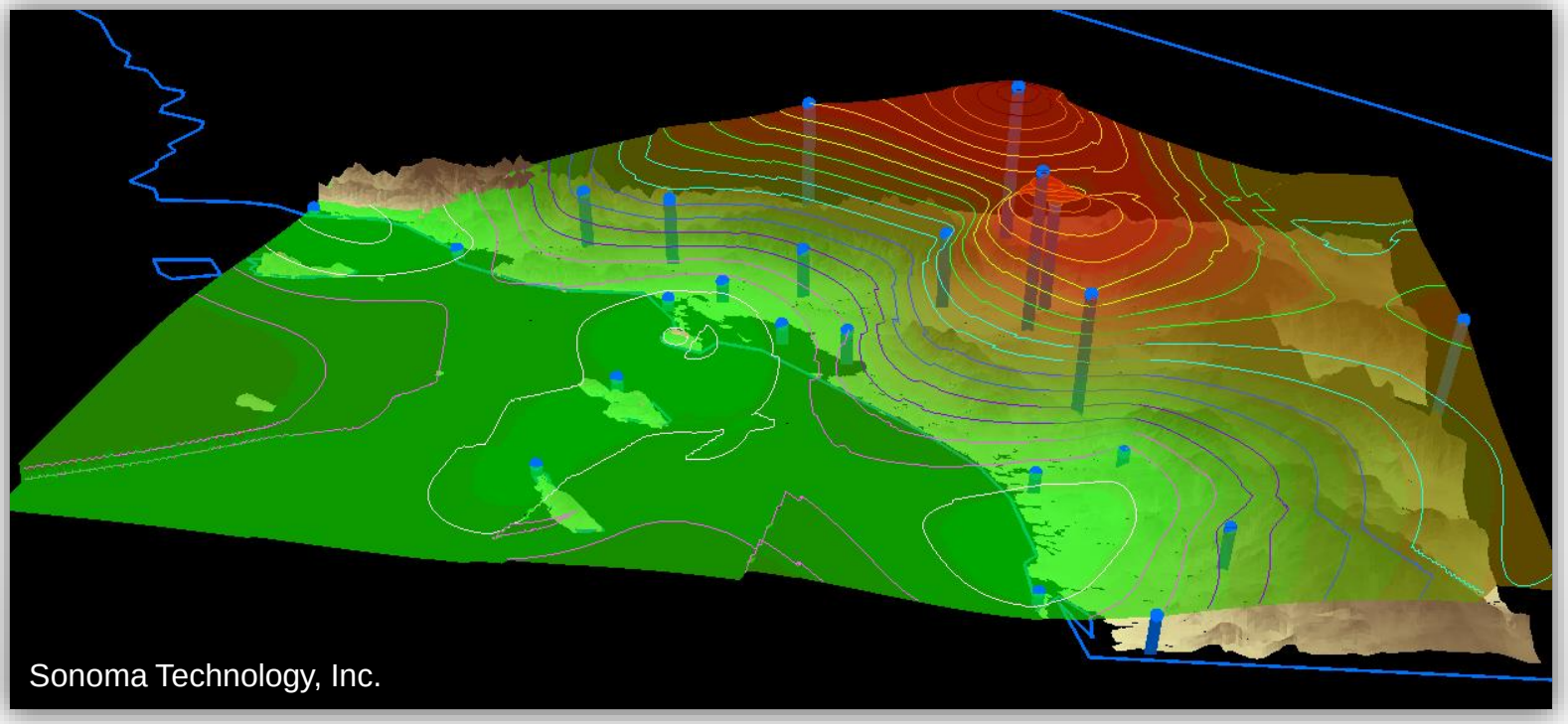
RWP/RASS BL heights



Ceilometer backscatter and ceilometer BL heights

Seattle, WA

Mixing Heights



Mixing heights derived from a network of radar wind profilers in Southern California for September 3, 1997, at 1500 PST. Profiler locations are shown in blue. Mixing heights range from ~200 (green) to 4000 (red) m above msl.

Applications to Air Quality

- Model assimilation and verification
- Daily forecasting
- Data analysis for understanding and characterization
  - Transport
  - Dispersion
  - Fumigation
  - Source contribution
- Exceptional event demonstrations

Photo by Don Blumenthal of STI on July 12, 1987

Instruments

	Wind Profiles	Temp. Profiles	Inversions	Mixing Heights	Moisture Profiles	Cloud Base Height
RWP	X			X		
RWP/RASS	X	X	X	X		
Doppler Lidars	X			/		
Sodars	X			/		
Radiosondes	X	X	X	X	X	X
Tethersondes	X	X	X		X	X
Radiometer		X	X		X	
Ceilometer				/		X

X = all instruments
/ = some instruments

RWP with RASS

- Pluses
  - Measures key parameters (winds, temp, mixing height)
  - Excellent height coverage (100 to 3500 m agl)
  - Long life
  - Unattended operations
- Minuses
  - High acquisition and repair costs
  - Substantial infrastructure
  - RASS is noisy
  - Few manufacturers

Irvine RWP with RASS

Doppler Lidar

- Pluses
  - Measures winds
  - Mixing heights (on some)
  - Very high time and vertical resolution
  - Unattended operations
  - Small sampling volume
  - Several types available
- Minuses
  - Doesn't provide data in or above fog/clouds
  - Expensive, but that is changing
  - Height coverage can be limited

Photo from Leosphere WindCube lidar manufacturer's website: http://www.leosphere.com/products/3d-scanning/windcube-100s200s400s

Sodars

- Pluses
  - Wind and mixing heights (on some)
  - Relatively low-cost
  - Can run on solar
  - High time and vertical resolution
  - Unattended operations
  - Several types available

Ontario Mini-Sodar

- Minuses
  - Main product is wind; other data products on some sodars
  - Limited height coverage (~200 to 800 m depending on model)
  - Limited height coverage in high winds
  - Noisy

Radiosondes

- Pluses
  - Measures key parameters (winds, temp, mixing, RH)
  - Relatively low acquisition cost
  - Portable
  - Good vertical resolution
  - Excellent height coverage
  - Long-history of use by the NWS
- Minuses
  - Manned operations
  - High operations cost for routine measurements
  - Non-continuous data

Photo from Radiosonde Museum of North America

Tethersondes

- Pluses
  - Measures key parameters (winds, temp, mixing, RH)
  - Relatively low acquisition cost
  - Portable
- Minuses
  - High operations cost for routine measurements
  - Non-continuous data
  - Low height coverage
  - Manned operations
  - Not deployable in windy conditions

Photo courtesy of NOAA ESRL

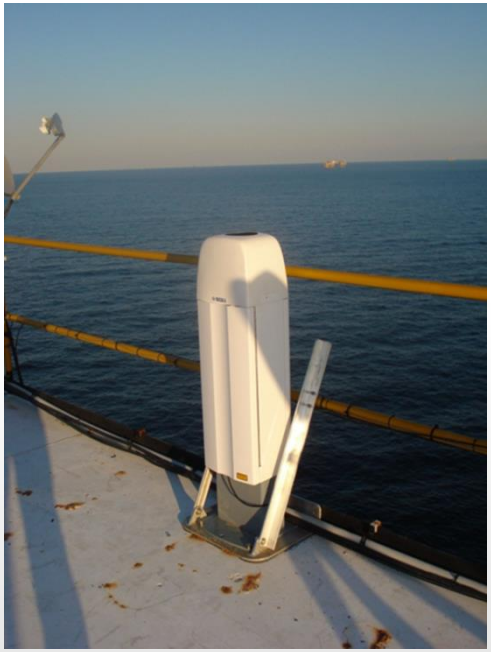
Microwave Radiometer

- Pluses
  - Measures temperature, RH, liquid water
  - Excellent height coverage (~10 to 10,000 m agl)
  - Unattended operations
  - High time and vertical resolution
- Minuses
  - No winds
  - Moderately high acquisition cost (~$150K)
  - Indirect measure of parameters (can lead to non-detects of inversions, for example)
  - Few manufacturers

Microwave Radiometer – Gulf of Mexico

Ceilometer

- Pluses
  - Measures cloud base height and mixing height (on some)
  - Excellent height coverage (10 to 10,000 m agl)
  - Unattended operations
  - High time and vertical resolution
  - Inexpensive to acquire and operate
- Minuses
  - No winds or temperature



Ceilometer-Gulf of Mexico

Instrument Summary

	Attributes				Rough Cost			
	Multiple parameters	All-weather data collection	Height coverage	Time resolution	Acquisition cost	Major repair cost	Operations cost per year	Infrastructure cost
RWP	***	***	***	***	$$$$$	$$$	$	$$
RWP/RASS	***	***	***	***	$$$$$	$$$	$	$$
Doppler Lidars	**	**	**	***	$$-$$$$	$$	$	$$
Sodars	**	***	**	***	$$	$	$	$
Radiosondes	***	***	***	*	$ - $$$	$	$$$	$
Tethersondes	***	*	*	*	$$	$	$$$	$
Radiometers	**	***	***	***	$$$	$	$	$$
Ceilometer	*	**	***	***	$	$	$	$$

Attribute Quality

*** Excellent
** Good
* Fair

Cost

$$$$$	~$300-400k
$$$$	~$150-250k
$$$	~$100-150k
$$	~$30-100k
$	~$5-30k

Ratings are qualitative and are based on many years of experience and selected interviews.

Closing Thoughts

- Day-to-day variability in air quality is mostly controlled by meteorology
- No silver bullet instrument
- Several important meteorological parameters
- Really depends on your needs, applications, and resources
- Cost for acquisition vs. operations can be inverse
- Technology is improving and costs are coming down

Contact

Clinton MacDonald

Branch Manager,
Meteorological and Air Quality Measurements

clint@sonomatech.com
707.665.9900

Sonoma Technology, Inc.
Air Quality Research and Innovative Solutions

sonomatech.com @sonoma_tech